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CLOUDS – THEIR PREDICTION AND SIMULATION

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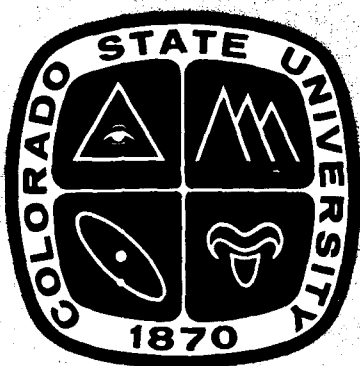
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Mesoscale forecasts of several FIRE II cirrus events has been repeated using newly developed microphysics schemes. Boundary layer cloud fractional coverage schemes has been tested for one of the FIRE I stratocumulus cases in which there was a transition from solid stratocumulus to broken cumuli. RAMS ability to simulate ordinary deep convective clouds has been evaluated for one of the CaPE case over the Kennedy Space Flight Center. New modules for cloud microphysics and radiation transfer have been written and the impacts of those schemes on cloud forecasting will be evaluated in the future.

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CLOUDS – THEIR PREDICTION AND SIMULATION

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Abstract

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Introduction

This represents an Annual Technical Report on AFOSR contract #AFOSR-91-0269 for the period 1 April 1992 – 31 May 1993.

1 Summary of Research Progress

1.1 Introduction

The ultimate goal of this research is to develop a comprehensive cloud modeling/forecast system that can be used to support U.S. Air Force operations. Most of the cloud forecast techniques so far have been either empirical or use cloud model schemes which have been developed in bits and pieces such that, for example, the boundary layer cloud scheme is totally different from middle and high clouds and neither scheme interacts directly with deep convective clouds. The physically-based cloud forecasting algorithms being used and tested in this research, on the other hand, are implemented in RAMS as an integrated, interactive package.

1.2 Modeling cirrus and middle-level layer clouds

Building on the real time cirrus forecasts of Thompson (1993) as part of his M.S. thesis, we have now performed repeat runs using the Chen and Cotton (1987) cloud radiation parameterization scheme for the 26 Nov and 6-7 December 1991 FIRE II cases. Longwave radiative cooling produced a cloud of greater ice water content and predictions of the time variations of cloud top and cloud base which were more in accord with observations.

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Using predicted soundings from the RAMS runs, since CLASS soundings were not moist enough at cirrus levels, 2D simulations of the 26 Nov case were run. These were done using the Meyers et al. (1992) natural ice nucleation scheme and the DeMott et al. (1993) homogeneous nucleation scheme. The results showed that predicted cirrus crystal concentrations were sensitive to both the concentrations of ice nuclei and haze/CCN in the upper troposphere.

1.3 Parameterization of the cloud-topped boundary layer

One of the biggest challenges in forecasting low level clouds is diagnosing or predicting cloud coverage. As part of his M.S. research, Dave Mocko has been testing various fractional cloudiness (FC) algorithms in RAMS using the Weissbluth and Cotton (1993) small-scale turbulence scheme. The FIRE I, 7 July 1987 case was selected fore testing the schemes since cloud cover went from solid status coverage, to broken cumuli, to no cloud cover. So far he has tested the Albrecht (1989), Kvamsto (1991), Sundqvist et al. (1989), and Betts and Boers (1990) schemes, all of which yield a transition in cloudiness in accordance with observations. The scheme that did the best job of predicting the observed gradual transition of FC was the Ek and Mahrt (1991) scheme. He still plans on implementing schemes by Bechtold et al. (1992), Manton and Cotton (1977) and Sommeria and Deardorff (1977).

1.4 Prediction of deep convective clouds

The most challenging cloud type to forecast is deep convective clouds. Ben Edwards has been investigating the feasibility of using the levels 2.5 w cumulus parameterization scheme developed by Weissbluth and Cotton (1993 in the forecast version of RAMS as part of his research. He has concentrated on the 29 July 1991 Convective Precipitation/Electrification Experiments (CaPE) case for initial testing. For these tests RAMS was set up with three grids with horizontal spacing of 80, 20, and 5 km, respectively. Results of this work are encouraging by not complete yet.

1.5 Cloud microphysics parameterization

As part of our cirrus forecasting research we are trying to distinguish between cirrus clouds having numerous small crystals and those having fewer bigger crystals. Jerry Harrington has developed a scheme in which ice crystals are fit in bimodal gamma distributions. The development of the new ice crystal scheme was initiated by assuming that both the pristine ice (PI) and snow can be described by complete gamma distributions of the form,

$$n(D) = \frac{N_t}{\Gamma(\nu)}(\frac{D}{D_n})^{\nu-1}\frac{1}{D_n}exp(-\frac{D}{D_n})$$

where D_n is the characteristic diameter of the distribution and ν is the shape parameter of the distribution. Equations were then formulated for the time rate of change of the distribution in which crystals are only allowed to grow/evaporate by vapor deposition; the subsequent transfer of crystals from one distribution to another is also considered and is described by a set of equations that allows for the flux of crystals across a certain threshold boundary. In order to account for the number of crystals lost from the PI distribution in an evaporative regime, a scheme has recently been developed that allows for the smallest crystals in the distribution to evaporate first. Before implementation into the RAMS model, this ice crystal scheme was tested in one dimensional lagrangian simulations.

This scheme has been implemented into the newest version of the RAMS model (version 3a) which has been set up to handle full distributions. Two dimensional simulations of the 25-26 November and 5-6 December FIRE II case days are now underway, and are being conducted as sensitivity tests of the new routines. In the future, 3-D simulations of the above FIRE II case days will be done using the new schemes in order to improve upon previous results.

1.6 Radiation parameterization

The cloud radiation scheme developed by Chen and Cotton (1987) does not respond to the presence of aerosol particles or hydrometeors, only their liquid water paths. Moreover, as shown by Heckman and Cotton (1993) the scheme becomes very costly when a large

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number of vertical levels is used which is important for cirrus and middle-level layer cloud predictions.

A new radiative transfer scheme has been developed which is a flexible two-stream model. It requires user-specified bands limits and gaseous absorption characteristics within the bands. Particulate impacts on the radiative transfer are included through anomalous diffraction theory, and are integrated over the assumed size distribution of the particulates. The code allows for one band which is not included in the calculation of the atmospheric energetics, which may be used to simulate a remote sensing instrument, i.e. a ceilometer recording particulate backscatter information in range bins. The code is being tested with the band structure used by Ritter and Geleyn (1992), which uses 8 broad-bands to cover the spectrum, 3 in the short-wave part of the spectrum, and 5 in the long-wave. A clear-sky comparison with the ICRCCM data (Ellingson and Fouqart, 1991) using these bands gave results well within acceptable levels. The cloud parameterization is currently being tested using the higher resolution simulations of Wong et al. (1993). As part of the package, an exponential sum-fitting routine is being developed which can be used to calculate the gaseous absorption characteristics for any given broad-band. The package is further being developed to allow different absorption characteristics for given gases a different vertical levels in the atmosphere. The full model will be implemented in RAMS.

2 Planned Research

2.1 Refinements in RAMS physical modules

Since both the concentrations and mixing ratios of hydrometeors affect the optical properties of clouds, Mike Meyers is introducing prognostic equations for the concentrations of hydrometeor species in RAMS as part of his Ph.D. dissertation. This new addition to the RAMs microphysics should be completed by early fall of 1993.

It is also planned to optimize the new radiation module so that it is more suitable for realtime forecasting applications.

2.2 Modeling of cirrus and middle-level clouds

We plan to re-run the 25-26 Nov and 5-6 Dec FIRE II cases with the refinements in cloud microphysics and radiation parameterizations described above. In addition, we will use the Weissbluth and Cotton (1993) small scale turbulence parameterization scheme in those runs.

2.3 Modeling cloud-topped boundary layer clouds

Once the evaluation of cloud fractional coverage schemes is completed with the 7 July 1987 case, it is planned to evaluate the schemes for an independent data set, preferably one over land.

2.4 Modeling deep convective clouds

It is planned to further evaluate RAMS ability to simulate convective clouds over South Florida using other cases from CaPE. An important part of that work will be to optimize the Weissbluth scheme so that it is more suitable for realtime forecasting applications.

3 List of Personnel

Researchers supported by this contract are listed below.

William R. Cotton	Principal Investigator
Graeme L. Stephens	Co-Investigator
Michael Weissbluth	Research Associate
Craig Tremback	Research Associate
Paul DeMott	Research Associate
Michael Meyers	Ph.D. graduate student
Jerry Harrington	M.S. graduate student
David Mocko	M.S. graduate student
Ben Edwards	M.S. graduate student (AFIT)
Gregory Thompson	M.S. graduate student

4 Publications Supported

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Flatau, Piotr J., 1992: Scattering by irregular particles in anomalous diffraction and discrete dipole approximations. Ph.D. dissertation, Colorado State University, Dept. of Atmospheric Science, Fort Collins, CO 80523, 140 pp. (Available as Atmos. Sci. Paper No. 517.)

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